Coupling Lean Thinking and Systems Thinking at the Enterprise Level

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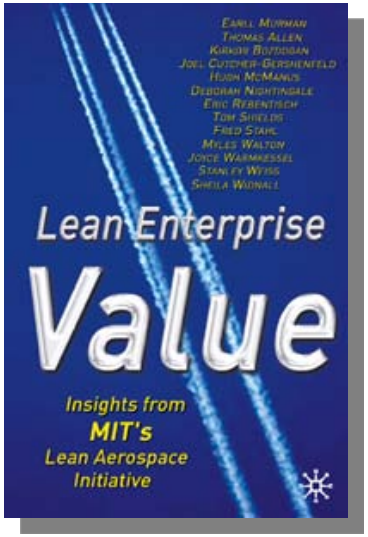
The 21st Century Enterprise Challenge



Aerospace has four core missions:

- Enabling the global movement of people and goods
- Enabling the global acquisition and dissemination of information and data
- Advancing national security interests
- Providing a source of inspiration by pushing the boundaries of exploration and innovation

These missions will never be routine and require the best technology and the best organizations

These enterprise level capabilities are at the intersection of lean thinking and systems thinking.

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Lean Aerospace Initiative Formed in 1993

- Industry
  - Airframe, engine, avionics, missile and space companies
- Government
  - Air Force agencies, system program offices, and headquarters
  - NASA, Army, Navy
  - Department of Defense
- Academia
  - MIT - Schools of Engineering and Management
  - Educational Network (2003)

A national consortium for research, implementation and diffusion of lean practices

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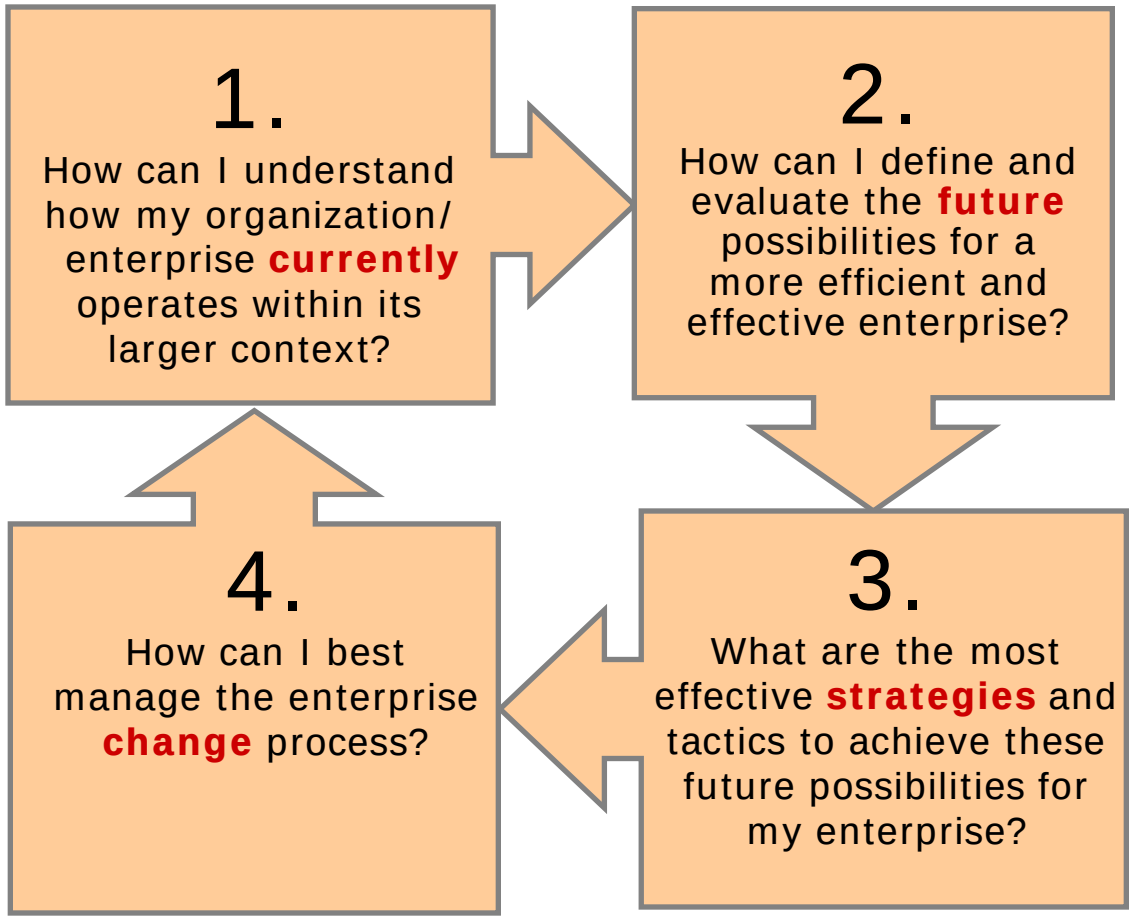
Four Grand Questions Derived from the Transformation Imperative



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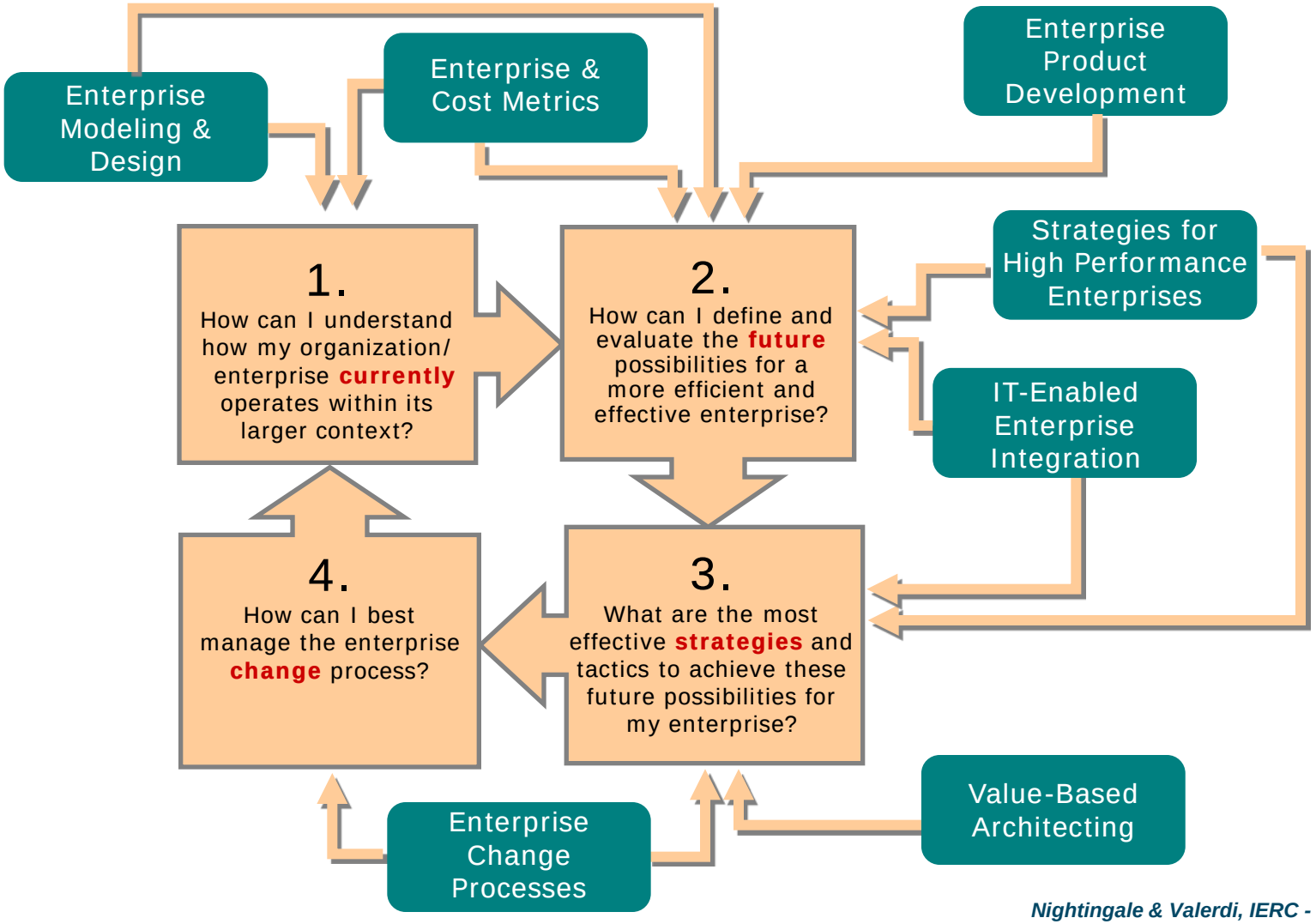
Seven Research Clusters to Answer the Four Grand Questions



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Lean Engineering: Doing the Right Thing Right

- Creating the right products…
  - Creating product architectures, families, and designs that increase value for all enterprise stakeholders.
- With effective lifecycle & enterprise integration…
  - Using lean engineering to create value throughout the product lifecycle and the enterprise.
- Using efficient engineering processes.
  - Applying lean thinking to eliminate wastes and improve cycle time and quality in engineering.

Source: McManus, H.L. "Product Development Value Stream Mapping Manual", LAI Release Beta, April 2004

Framework based upon a decade of Lean Aerospace Initiative research & industry/government implementation

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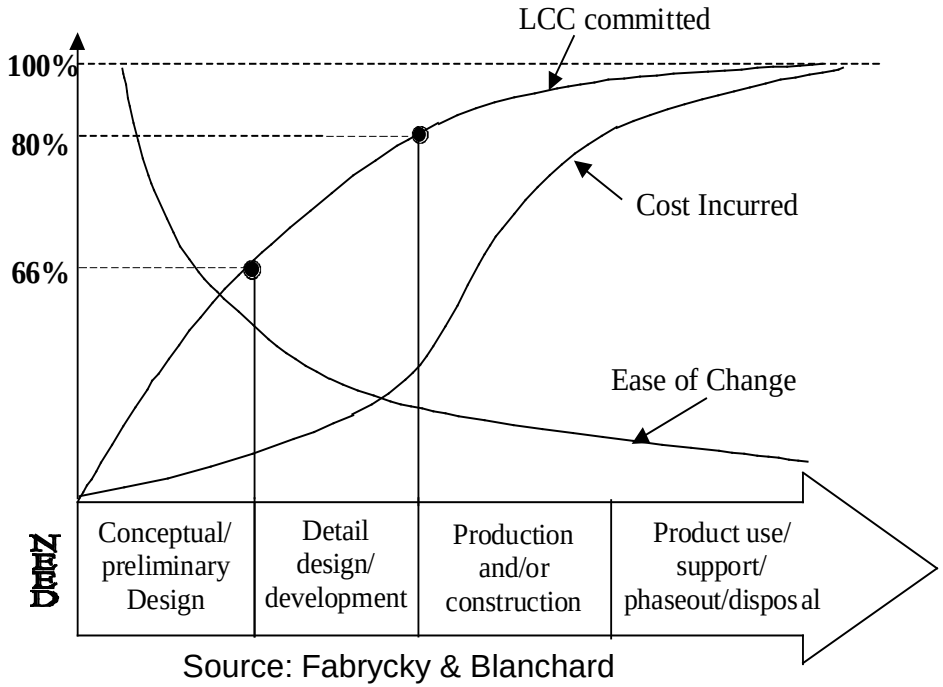
Engineering Drives Cost



Source: Fabrycky & Blanchard

"Fuzzy Front End" Challenges

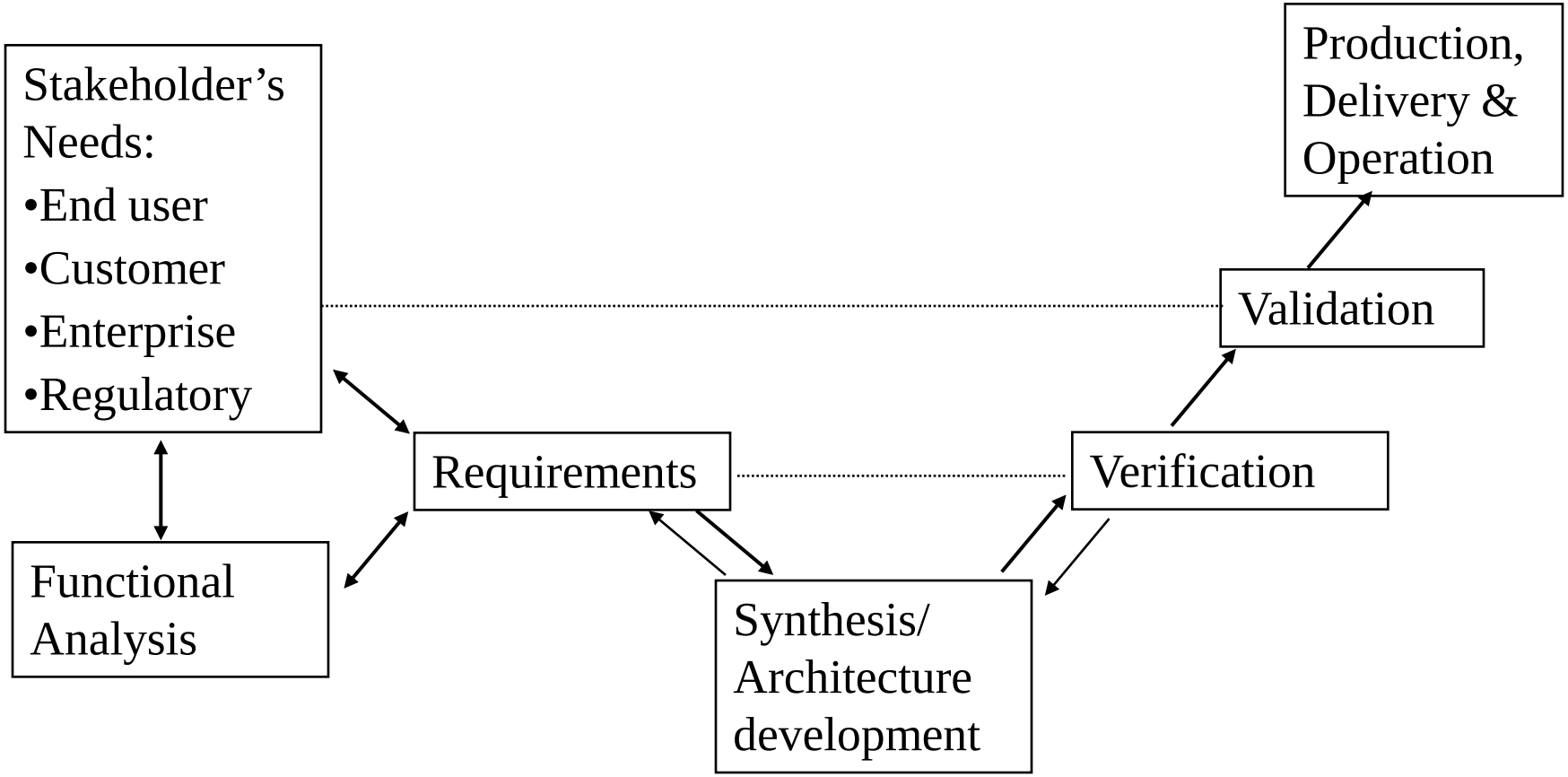
Understanding what the customer values

Deciding which product to pursue from amongst many opportunities

Selecting the right product concept

Early decisions are critical - Disciplined lean systems engineering process is essential

Simplified Systems Engineering Process



Systems engineering process is applied at multiple levels: system, subsystem, component.

Source: Adapted from Jackson, S. *Systems Engineering for Commercial Aircraft*

Source: "Lean Engineering", LAI Lean Academy™, V3, 2005

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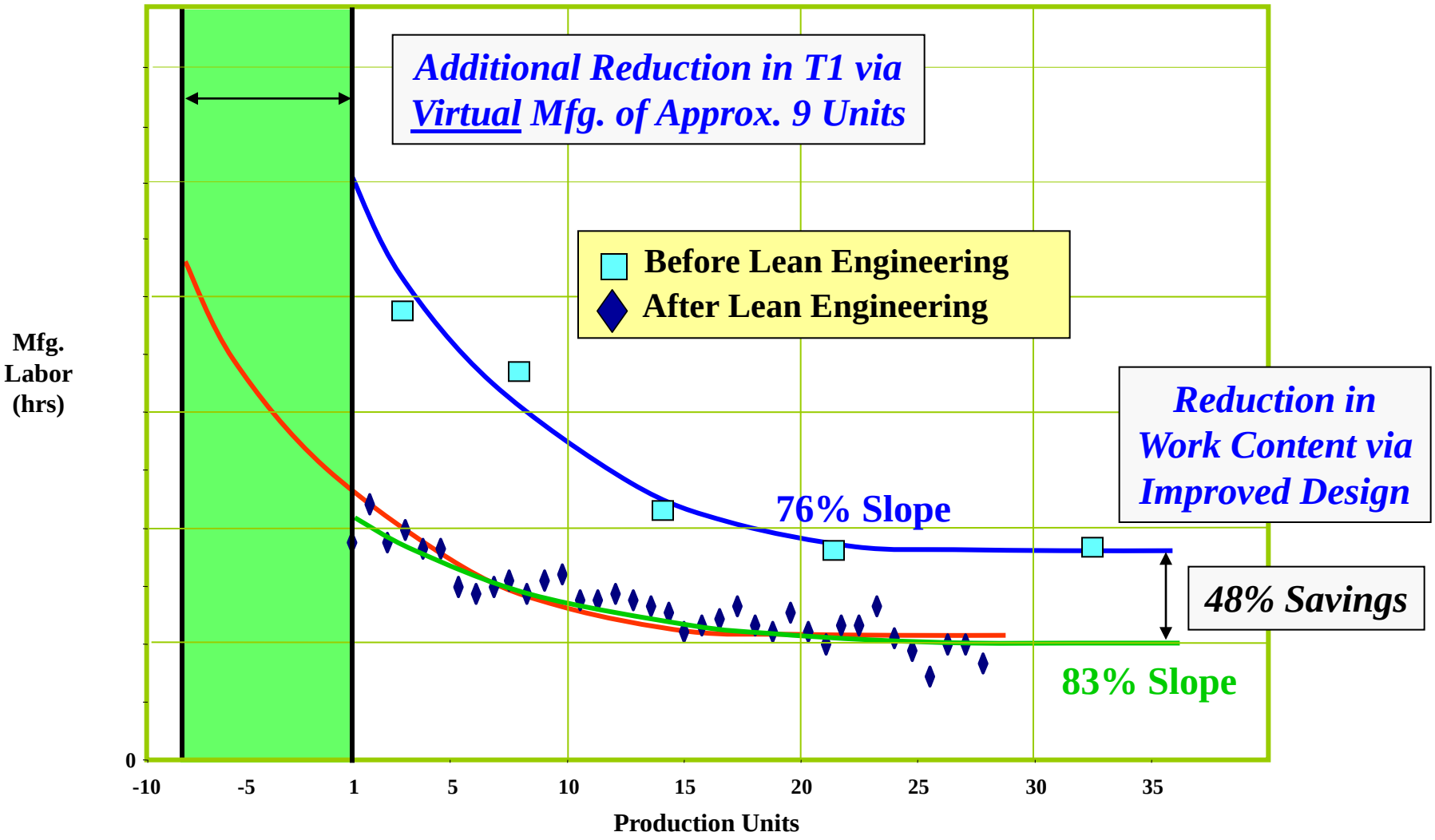
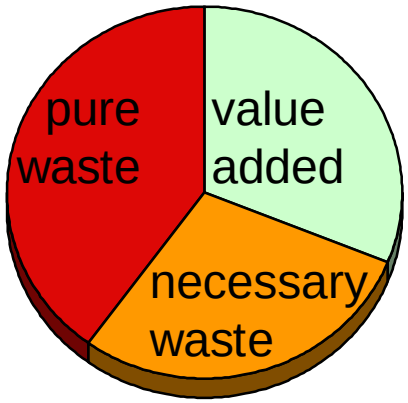
Lean Engineering Reduces Manufacturing Labor



Source: "Lean Engineering ", John Coyle (Boeing), LAI Executive Board Presentation, Jun 2000

Waste Exists in Engineering



- Effort is wasted
  - 40% of PD effort “pure waste”, 29% “necessary waste” ***(workshop opinion survey)***
  - 30% of PD charged time “setup and waiting” ***(aero and auto industry survey)***

- *Time* is wasted
  - 62% of *tasks* idle at any given time ***(detailed member company study)***
  - 50-90% task idle time found in Kaizen-type events

Source: McManus, H.L. “Product Development Value Stream Mapping Manual”, LAI Release Beta, April 2004

Source: “Lean Engineering”, LAI Lean Academy™, V3, 2005

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Applying Lean Fundamentals to Engineering

Lean Thinking Steps	Manufacturing	Engineering
Value	Visible at each step Goal is defined	Harder to see Goal is emergent
Value Stream	Parts and materials flows	Information and knowledge flows
Flow	Iterations are waste	Planned iterations OK Must be efficient
Pull	Driven by takt time	Driven by enterprise needs
Perfection	Process repeatable without errors	Process enables enterprise improvement

Source: McManus, H.L. ŅProduct Development Value Stream Mapping ManualÓ LAI Release Beta, April 2004

Key step to application of lean thinking is the

Product Development Value Stream Mapping- PDVSM

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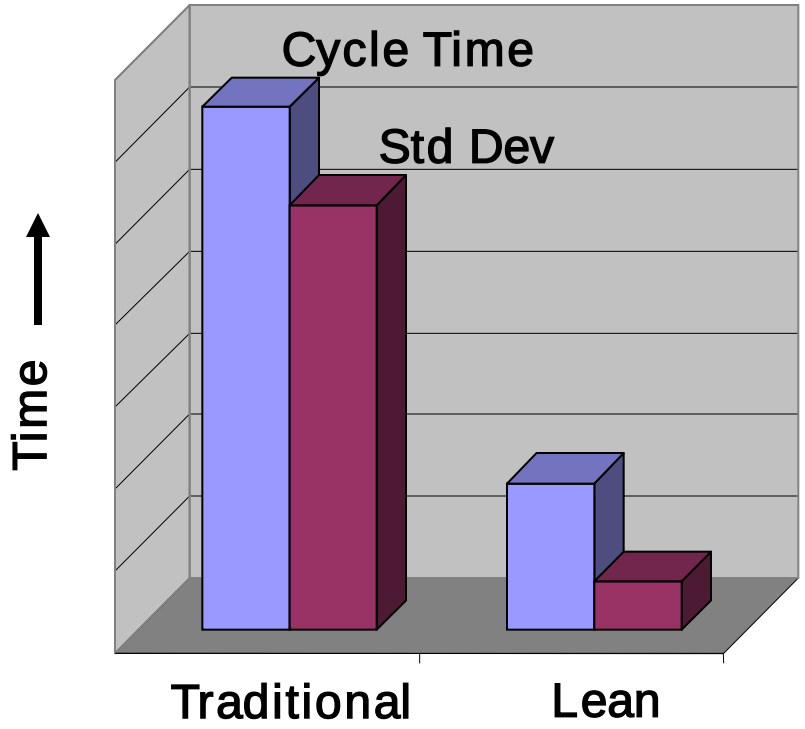
Results of Applying Lean to Engineering Release Process

- Value stream mapped and bottlenecks found
- Process rearranged for sequential flow
- Waiting and delays removed



- Reduced Cycle time by 73%
- Reduced Rework of Released Engr. from 66% to <3%
- Reduced Number of Signatures 63%

Source: Lean Aerospace Initiative

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Lean Applies to Development of Many Types of Products

Value-stream based rationalization of processes yields impressive results across a range of environments:

- Aircraft structure drawing release: 75% cycle time, 90% cycle time *variation*, and 95% rework rate reductions
- Satellite environmental testing: 41% cycle time, 58% labor, 76% material, and 92% travel reductions
- Printed circuits: 23% design cycle time reduction
- Avionics: 74% change order cycle time reduction

Combined with technological changes at bottleneck processes, results can be even more dramatic:

- Electronic modules: increase yield from 10% to 90%
- IC design: 70% cycle time, 80% cost reductions

Sources:Lockheed Martin, Rockwell Collins, ITT

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Systems Engineering and Lean Thinking

- ***Systems Engineering*** grew out of the space industry in response to the need to deliver technically complex systems that worked flawlessly upon first use
  - SE has emphasized technical performance and risk management of complex systems.
- ***Lean Thinking*** grew out of the Japanese automobile industry in response to the need to deliver quality products with minimum use of resources.
  - Lean has emphasized waste minimization and flexibility in the production of high quality affordable products with short development and production lead times.

Apparent differences overcome by common objectives, emerging vision of lean enterprise

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Lean and SE Commonalities

- Lean and Systems Engineering: processes that evolved through experience and practice
  - Shaped by different contexts with different areas of emphasis
  - Bodies of Knowledge (BOKs) based upon observed best practices
- Both emphasize process as a key enabler
- Both have the objective of better delivering best lifecycle value to the customer (end user)
  - Lean: right product at the right time and cost
  - SE: right product that meets customer requirements on schedule and budget

Can the combination of Lean and SE BOKs lead to a more effective and efficient SE approach?

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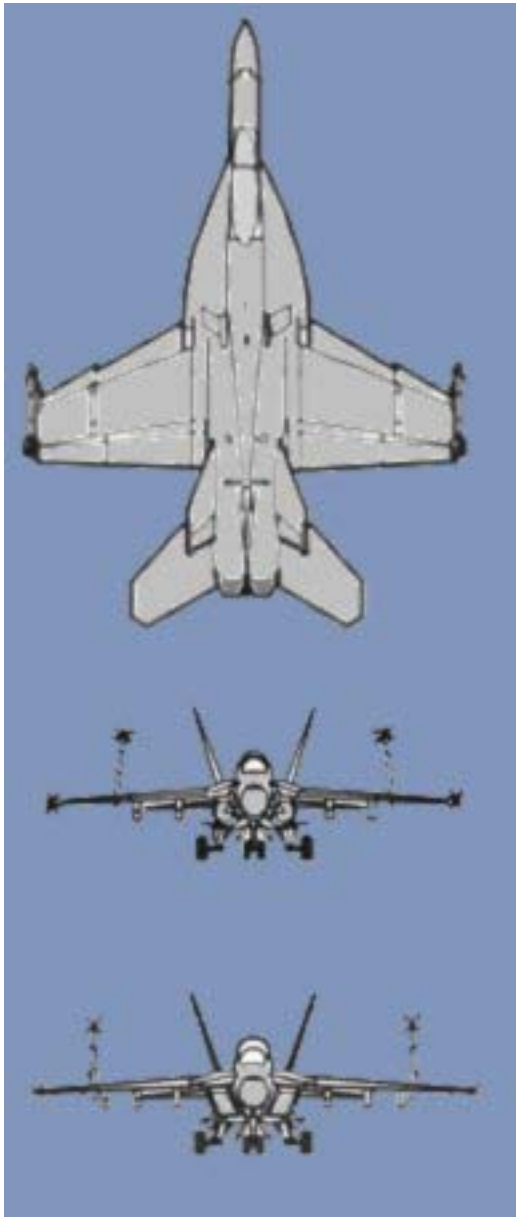
F/A-18E/F Systems Engineering

- Rigorous Requirements Flowdown
- Disciplined Technical Reviews
- Configuration / Data Mgt.
- Systems Cost-effectiveness/
- LCC Trade studies
- Producibility / DFMA
- Risk Management / TPM
- Program Independent Audits
- Reliability/ Maintainability/Safety
- Human factors engineering
- Integrated Logistics

IPPD Environment



Source: Al Haggerty, "The F/A-18E/F Super Hornet as a Case Study in Value Based Systems Engineering", INCOSE Panel on Lean Systems Engineering, June 2004

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The Process

HAND PICKED LEADERS

INTEGRATED MANAGEMENT CONTROL SYSTEM

INTEGRATED PRODUCT DEFINITION

SYSTEMS ENGINEERING

CONFIGURATION CONTROL

LEADERSHIP PRINCIPLES

RISK MANAGEMENT

WEIGHT MANAGEMENT

- CUSTOMER SATISFACTION
- OPEN, HONEST COMMUNICATION
- SUPPLIERS AS PARTNERS
- TEAMWORK
- PERFORMANCE TO PLAN

CO-LOCATED TEAMS

EARNED VALUE MGT.

SUPPLIER INTEGRATION

Source: Al Haggerty, "The F/A-18E/F Super Hornet as a Case Study in Value Based Systems Engineering", INCOSE Panel on Lean Systems Engineering, June 2004

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Lean Enterprise Principles Applied to F-18E/F

- **Continuous Improvement**
- **Optimal First -Unit Delivered Quality**
- **Metrics Tracked Weekly Across the Extended Enterprise**
- **Seamless Information Flow (USN, NGC, GE Engines, Suppliers)**
- **Decisions Made at the Lowest Level of WBS Via "Delegated" RAA**
- **Joint Configuration Change Board**
- **Disciplined Weekly Earned Value Mgt. & Reporting**

Performance To Plan!

Source: Al Haggerty, "The F/A-18E/F Super Hornet as a Case Study in Value Based Systems Engineering", INCOSE Panel on Lean Systems Engineering, June 2004

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THE PROCESS WORKS!

- **42% Fewer Structural Parts**
- **The Parts Fit the First Time**
- **1029 Lbs. Below Specification Weight**
- **Reduced Engineering Change Activity**
- **Development Completed On Budget- $4.9B**
- **1ST Flight Ahead of Schedule!**

Achievement Recognized:1999 Collier Trophy!

Source: Al Haggerty, "The F/A-18E/F Super Hornet as a Case Study in Value Based Systems Engineering", INCOSE Panel on Lean Systems Engineering, June 2004

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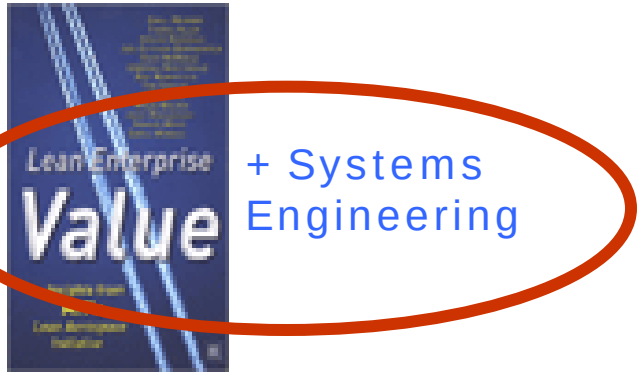
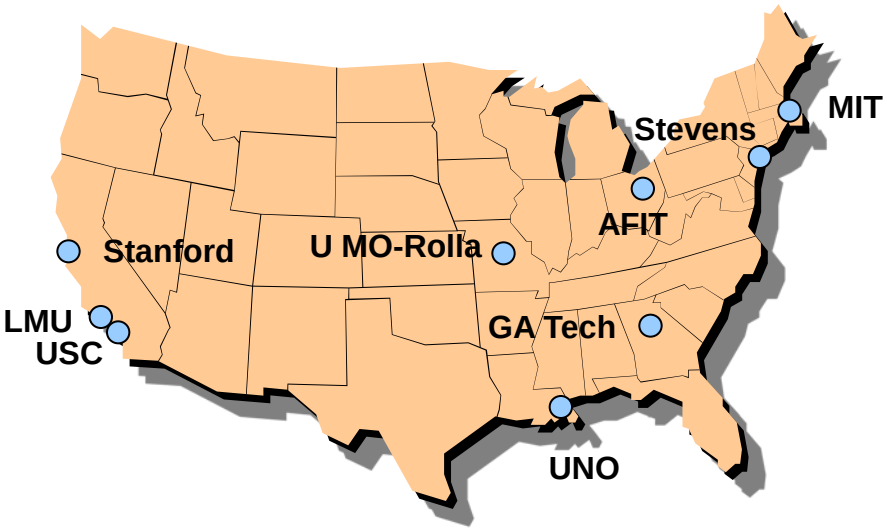
LAI EdNet Lean SE Working Group

- SE processes recognized as sound, but not always applied effectively
- "Lean" provides an approach to maximize value while minimizing wasted effort
- Synergies of lean practices and SE practices are being explored
- Working name is "Value Based SE"





Possible WG outputs

- Lean SE Learning community
- Value based Systems Engineering Framework
- Course materials
- Research

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Value Based Systems Engineering

- Emphasize common objectives for Lean and SE: *Value*
  - Overarching objective of value based systems engineering is to deliver the expected value to the system stakeholders
  - Critical functions are those that create/deliver that value
  - Measures of success are based on value created/delivered to stakeholders
- Value based SE is an enterprise level function
- Value based SE must be scaleable, from systems of systems to major subsystems
- Software Engineering community is already making progress
  - *"Value-Based Software Engineering"* by Biffl, S., Aurum, A., Boehm, B., Erdogmus, H., Grunbacher, P., (Eds.), Springer, 2005.

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Lean Enterprise Model - A Tool for Benchmarking Lean Enterprises

Meta-Principles

Responsiveness to Change Waste Minimization

Enterprise Principles

Right thing, in the right place, at the right time, in the right quantity
Effective relationships in the value chain
Continuous improvement
Optimal first unit delivered quality

Overarching Practices

Human Oriented Practices

- Promote Lean Leadership at all Levels
- Optimize Capability & Utilization of People
- Develop Relationships Based on Mutual Trust & Commitment
- Continuously Focus on the Customer
- Make Decisions at Lowest Possible Level
- Nurture a Learning Environment

Process Oriented Practices

- Assure Seamless Information Flow
- Maintain Challenge of Existing Processes
- Implement Integrated Product & Process Development
- Identify & Optimize Enterprise Flow
- Ensure Process Capability and Maturation
- Maximize Stability in a Changing Environment

Enabling and Supporting Practices

Source: web.mit.edu/lean

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Lean SE Tool: Draft Value Based Systems Engineering Model

Meta Principles

Right Job

Job Right

Metrics:

SE Enterprise Principles

Engineering Excellence

Leadership & Organizational Effectiveness

Programmatic Success

Efficient Process Execution

Overarching Practices

?	?	?	?	?	?
?	?	?	?	?	?

